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ABSTRACT

This report presents the proceedings of a consortium at which leading developmental neuroscientists from across the United States and Canada met at Johns Hopkins University to explore the relationship between children's health and learning and to propose policy changes. Early brain development and its relationship to intelligence, learning, and memory were reviewed, and a number of topics relating to early brain development were discussed. These included the effects of environment, such as degree of nurturing, maternal well-being, and enriching experiences; the effects of stress, based on endocrine system response; the increased academic failure and social costs that result from exposure to lead; the neurobiological consequences that result from prenatal cocaine exposure; and language development and impairment. The meeting proposed four recommendations: (1) every mother and baby must receive early health care; (2) infants and children must receive early screening for learning disabilities; (3) the discoveries of neuroscience must improve programs for all children by demystifying science and uniting scientific knowledge with health and education services; and (4) funding for basic research must be supported. The report of the meeting is followed by a reference list and lists of meeting participants and consortium members. A description of the consortium is included. (BC)

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Healthy Brain Development:

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National Commission to Prevent Infant Mortality
Institute for Educational Leadership

Healthy Brain Development:

Precursor to Learning

National Health/Education Consortium
January 1991

Healthy Brain Development:
Precursor To Learning

Children must be healthy to be able to learn, and they must be educated to assure their optimal health. Millions of infants and children, however, lack access to health care or suffer from poor health, leaving them vulnerable to physical and learning disabilities and other long-term problems such as illiteracy, school failure, and juvenile incarceration. The health and learning ability of a child are inextricably connected; yet health and education programs and policies are separately developed, financed, and operated, and health professionals and educators do not always work together on behalf of children.

The NATIONAL HEALTH/EDUCATION CONSORTIUM was formed to bring together leaders from the health and education communities to begin to design strategies to more effectively integrate health and education services and programs for children in this country.

The close relationship between children's health and learning ability has been demonstrated not only through practical experience, but also through behavioral and neurobiological research. These research findings, however, are little understood and have not been translated into program and policy changes to benefit children. To better explore this critically important facet of the health/education connection, a meeting of leading developmental neuroscientists from across the United States and Canada was convened on December 6, 1990. The meeting was moderated by Joseph Coyle, M.D., Professor of Child Psychiatry at Johns Hopkins University School of Medicine. This report presents the proceedings from the scientists' discussion and represents the first in a series of reports to be released by the NATIONAL HEALTH/EDUCATION CONSORTIUM.

Given the explosion of new discoveries about the early development of the central nervous system, the neuroscientists were asked to define the neurobiological components of learning and to identify factors that may adversely affect the learning process. Their discussion provided a rare opportunity to move basic research knowledge into the policy arena. The hope is that these and other neuroscientific findings will be used by policymakers and others to better develop and evaluate programs and services for individuals.

Early Brain Development

Weighing only three pounds, the brain controls and coordinates virtually every function of the body, including thoughts, emotions, sensations, perceptions, and the vital tasks of learning and memory. In any discussion about the health and education of children, the development and nurturing of the brain is a key component. This wondrous organ is the most fundamental building block for healthy, educated and successful individuals.

By the time of birth, an infant's brain, at two-thirds the size of an adult brain, is remarkably complete. Recent research has found that three months before birth, a fetus has already developed 10 billion neurons, nearly the full complement at brain maturity. Neurons are the single nerve cells that serve as the functional unit of the nervous system. They are created at the average rate of 40,000 every minute for the first 180 days after conception.

As the neurons develop, the process of opening communication lines between them begins. This "wiring" between cells is called synapse formation. The synapses form the basis for all future neural communication within the body.

Each mature brain cell has, on average, about 10,000 synapses which largely develop during the first few months after birth. After this period, the process slows, although these critical connections continue to develop throughout early childhood until school age. Healthy neuron and synapse formation is essential for the development of learning functions.

Benjamin Bloom, Professor at the University of Chicago and a leading expert in human development, wrote 25 years ago in his book, *Stability and Change in Human Characteristics*, "General intelligence appears to develop as much from conception to age four as it does during the 14 years from age four to age 18." In fact, learning begins as early as the first days of life. Michael Leon, Ph.D., Professor of Psychobiology at the University of California at Irvine, suggests that complex associative olfactory learning, such as recognizing and responding to the mother's odor, takes place in newborns within the very first 48 hours of life.

The function of learning and memory is not a unitary process of the brain, but rather it involves several neural mechanisms which develop at different times during infancy, according to Jocelyne Bachevalier, Ph.D., researcher at the National Institute of Mental Health. Because learning and memory are dependent on the healthy development of many parts of the brain which mature at different times, the presence of a nurturing, well-protected environment is crucial. Working to ensure the healthy development of the brain in the early stages of life is fundamental to later cognitive functioning.

Brain Development and the Effects of Environment

Initial stages of neurological development can dramatically influence a child's life options and possibilities. At life's beginning, the brain's potential can be enhanced or

hindered by the child's environment. The intricacies of brain growth occur in response to both genetic pattern and stimuli in the environment. Genetic makeup as well as the degree of nurturing in a child's world determine developmental outcome.

Even the mother's physical and emotional well-being can affect the development of the brain of the fetus. If a pregnant woman is suffering from poor nutrition or is under significant emotional stress during critical brain growth periods during pregnancy, her child may develop serious mental deficiencies.

The research of William Greenough, Ph.D., Associate Director for the Beckman Institute at the University of Illinois Urbana-Champaign, indicates that an infant's experiences during development can have profound and enduring effects on brain organization and behavior. Dr. Greenough's research involves rats raised in a complex, enriched environment, in which groups of animals live in large cages filled with toys and other objects and receive opportunities to explore other toy-filled environments.

It appears that enriching experiences cause neural activity which triggers synapse formation. Animals raised in a complex environment have more connections per neuron. Different forms of experience produce different patterns of brain development. While not absolutely permanent, these structural changes far outlast the experiences that induce them. Animals reared in the complex environment also tend to be superior at learning complex tasks, such as mazes and visual discrimination.

These findings suggest that infants raised in enriched environments with a range of activities and objects to stimulate their activity are likely to experience more complex brain development and learning. Interaction with parents through play and stimulation enhances these effects. Babies who are exposed to play and exercise seem to experience an adaptation in their brain's metabolic systems so that they become more competent to support high levels of physical activity as well as later motor skills development. These infants' immune systems may also be improved.

Brain Development and the Effects of Stress

The close interaction between hormones and the brain is another major influence in the development and maintenance of learning processes. The endocrine system plays a vital role both before and after birth, as well as in adulthood. Especially before birth, when brain cells are increasing by thousands per minute, abnormal hormonal secretions can have lasting effects on brain structure and function and can alter the growth and differentiation of neurons in the brain, thereby affecting learning.

One of the first discoveries about the connection between endocrinology and learning revealed thyroid hormone abnormalities among children who were slow learners. More recently, Bruce McEwen, Ph.D., Professor of Neuroendocrinology at Rockefeller University, has shown in experimental animals that a brief exposure to thyroid hormone immediately after birth leads to permanent structural alterations in neurons and other structures of the brain important for memory.

A child's experiences can increase or decrease the output of hormones through the endocrine system. When an alteration of hormone release occurs regularly or is sustained over time during critical periods of development, the resulting impact on the brain can be permanent. Research now suggests that severe recurrent stress, such as the social stress a child feels from subordination and defeat, will increase stress hormone release and may lead to damage of neurons within the learning centers in the brain.

Conversely, other research has shown that rats that are "handled," that is, positively stimulated and exposed to short, beneficial periods of stress during early development, are calmer than unhandled rats. The handled rat's endocrine system develops more efficiently, allowing the animal to better handle stress later in life. Michael Meaney, Ph.D., researcher at the Douglas Hospital Research Center in Montreal, Canada, and an expert in the field of neuroendocrinology, has discovered that handling also appears to slow down the aging process.

These results imply that events occurring during the prenatal period, infancy and childhood can have a disproportionately powerful influence on the entire life of a person by affecting how the endocrine system responds to stressful occurrences in adult life. Positive, stimulating experiences in early life promote better adaptation to later challenges. At the same time, stressful life experiences, whether associated with malnutrition or with social stresses from the family or the environment, may have a destructive impact on the brain and the rest of the body.

Exposure to Lead and Academic Failure

Diocorides, a Greek physician, said in the 2nd century BC that "Lead makes the mind give way." Lead, the best studied and most prevalent neurotoxin, produces brain damage in children. The Federal Agency for Toxic Substances and Disease Registry concluded that even very low levels of lead cause neurotoxicity.

One American child in six has toxic levels of lead in his or her blood. Lead can also be transferred from mother to fetus. Each year, 400,000 newborns are delivered with toxic levels of lead. For African-American children in poverty, the rate of toxic blood lead levels is 55 percent!

"Lead is not a problem for poor inner city minorities alone. But like many of the assaults upon decent living, the poor receive an unfair dose," states Herbert Needleman, M.D., Professor of Pediatrics at the University of Pittsburgh School of Medicine, who has spent many years studying the deleterious effects of lead.

Remarkably, in 1979, he found that even children who showed no symptoms of lead exposure often had elevated lead levels in their teeth, lower IQ scores, poorer speech and language processing, and disorderly classroom behavior.

When these same children were re-evaluated in the fifth grade, Dr. Needleman's group found that those children with high tooth lead had more need for special services such as speech therapy, remedial reading and behavioral counselling. Their IQ scores were lower and their rate of repeating grades was significantly higher. These children were

then followed into adulthood. Having high levels of tooth lead carried a seven-fold increase in the risk of non-graduation from high school and a six-fold increase in the risk of reading disability.

The annualized costs, estimated in 1979, for medical care, remedial education and lost income for adults who have been poisoned by lead is 400 million to 1 billion dollars. The social costs are staggering as well. Dr. Needleman has hypothesized that the disorderly behavior of criminals is a result, in part, of disorders in the brain caused by lead.

Children who live in homes built prior to 1970, when the lead content of paint was first regulated, are at greatest risk of exposure. Despite society's awareness of the dangers of lead and how to prevent exposure, 2 million homes in the United States still have leaded surfaces and are inhabited by children. Future lead toxicity must be abated through more intensive programs targeted at safely deleading and rehabilitating housing and by promptly screening and treating all at-risk children.

Neurobiological Consequences of Prenatal Cocaine Exposure

With the prevalence of cocaine and crack cocaine abuse in society, the developmental and learning difficulties of children who are prenatally exposed to cocaine is becoming a major challenge to the health and education fields. Use of cocaine by a pregnant woman can cause the blood vessels in the placenta to constrict, diminishing oxygen supply to the fetus. This can result in physical malformations as well as damage to the baby's central nervous system.

Newborns who have been prenatally exposed to cocaine are typically hypersensitive. They often suffer from uncontrollable body tremors and have trouble adapting to their surroundings. These infants are poor sleepers and often cry when awake. They are difficult to soothe and tend to have abnormal reactions to such things as acoustic startle. Perhaps most disturbing, these infants typically have difficulty forming attachments and emotional bonds. They also are more likely to be born low birthweight and are thus at risk for the health and learning problems associated with low birthweight such as blindness, deafness, cerebral palsy and mental retardation.

Current literature indicates that prenatal cocaine exposure in infants affects learning and memory. As these children begin to enter the school system, teachers will increasingly be forced to cope with special behavioral and learning problems. Many cocaine-exposed children have difficulty learning in the normal classroom environment. Rather, they require early and intensive developmental attention from instructors who are trained to respond to the needs of these children.

In an effort to understand the neurobiological alterations that take place from prenatal cocaine exposure, Diana Dow-Edwards, Ph.D., Professor of Neurosurgery at the State University of New York Health Science Center in Brooklyn, is studying the effects on rats. Indeed, she has found that exposed rats suffer from learning and memory disorders. Cocaine exposure produces specific neurochemical alterations which persist until adulthood. Apparently, cocaine causes long-term effects in those regions of the brain undergoing synapse formation at the time of drug exposure.

As with other environmental assaults, the neurobiological effects of prenatal cocaine exposure must be considered in the context of the mother's socioeconomic status, access to prenatal care, and general lifestyle. These factors, in addition to the biological effects of cocaine exposure, can severely alter a child's ability to grow and develop a capacity for optimal learning and memory.

The Brain and Language Development

As Co-Director of the Center for Molecular and Behavioral Neuroscience at Rutgers University and a leading researcher in language development and learning disabilities, Paula Tallal, Ph.D., has sought to understand the causes and outcomes of specific developmental language disorders. For most children, learning their native language develops naturally, without any special instruction or training. The pattern of language development is so uniform across the many languages of the world that scientists have suggested that "linguistic universals" may be innately structured in the brain. Despite the ease with which most children naturally learn to speak, some children have great difficulty learning language.

One of the most surprising discoveries is that developmental language impairments are not specifically linguistic. Rather, a basic impairment in sensory information processing affects the brain's ability to integrate incoming information at a normal rate.

Therefore, for a child who has great difficulty in processing streams of information at a normal rate, understanding speech poses a particular road block. Their ability to keep up with and process sounds and words is severely impaired. Dr. Tallal's research indicates that reading disabilities may stem from earlier language disabilities which result from this inability to process rapidly changing sounds and words.

Using non-invasive testing procedures to study the brain, Dr. Tallal has discovered anatomical and structural abnormalities in the brains of children with specific developmental language impairment. These abnormalities correlate with a reduction in verbal IQ, a delay in learning to speak, difficulty in processing sounds and words, and impaired memory. Children with preschool developmental language impairments are at extremely high risk for school-age learning disabilities. With early and proper diagnosis, these children can receive the special attention they need to be successful in school.

Recommendations

Recent discoveries within neuroscience can serve to enlighten the health and education communities about the inextricable linkages between health/development and learning. The challenge for scientists, practitioners and policymakers is not only to be cognizant of the very fundamental relationships between healthy development and the ability to learn, but also to translate scientific findings into practical and policy changes.

Four specific recommendations evolved from the meeting of the neuroscientists:

Every Mother and Baby Must Receive Early, Comprehensive and Preventive Health Care

Prenatal and infant health care can make the difference between a child well equipped to meet life's challenges or a child destined to having learning disabilities and dropping out of school. Before birth, the development of a child's delicate brain is affected by the mother's physical and mental state. During infancy, the child must be nurtured and protected in order for critical neural circuits to be established. Unless the commitment exists to provide adequate access to comprehensive maternity and infant care, society will be forced to contend with the care and treatment of unhealthy children who, through no fault of their own, grow up with long-term disabilities or have difficulty becoming self-supporting adults.

Infants and Children Must Receive Early Screening, Diagnosis and Treatment for Learning Disabilities

New evidence indicates the exciting prospects of early intervention in promoting the optimal development of children at risk of learning disabilities. Children's learning ability, basic functioning and school performance can be improved. Even very high-risk children who historically have been forgotten can be helped.

Only through early identification of problems and early interventions can these children be given the hope of successful educational outcomes. Early screening and diagnosis programs for hearing, vision, anemia, lead exposure and other health problems are vitally important as are early intervention services that involve families. Waiting to treat children's learning disabilities until they are in school is often too late to improve their chances for success.

The Discoveries of Neuroscience Must Be Used to Improve Programs and Policies for All Children

The wondrous discoveries of neuroscience offer many lessons about the development of children's minds. A major obstacle in applying these lessons to develop programs and policies for children lies in demystifying and translating neuroscientific findings to practitioners and policymakers. Creating interest and understanding about the science world to health and education professionals will better link what is known to what is practiced. Involving the scientific community in the training of health and education professionals and school curriculum design also would help to bridge this gap.

The marriage of scientific knowledge with health and education services will lead to better and more appropriate care for children. The interesting mix of scientists, health professionals, educators, business leaders and policymakers brought together for the Neuroscience Meeting typifies the unified effort necessary to strengthen the awareness of children's needs.

Funding for Basic Research Must Be Supported

Support from both public and private sources for scientific research is vital for discovering the causes and treatments for neurobiological defects and learning disabilities. Funds, however, are not keeping pace with the need. For example, currently, only ten to twenty percent of grants approved by the National Institutes of Health for neuroscience research are being funded. Support for research that bridges the findings from developmental neuroscience with clinical settings is especially important. Only through cross-over from basic science to clinical experience can the health and education systems benefit from new discoveries.

Conclusion

A child's ability to learn and succeed in school is determined well before he or she walks in the school doors. It begins with the development of the most basic elements of the brain. Although it is impossible for parents or physicians or teachers to see a child's nerve cells and synapses, neuroscience reveals the importance of their healthy growth and maturation. By encouraging further research into the discoveries of the brain, the science community can continue to enlighten the health and education worlds about healthy options for children. Through available and adequate health care and education systems these important findings can be applied to improve services to benefit all children.

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American Association of Colleges for Teacher Education
American Association of School Administrators
American College of Nurse-Midwives
American College of Obstetricians and Gynecologists
American Federation of Teachers
American Hospital Association (MCH Section)
American Medical Association
American Nurses Association
American Public Health Association
American School Health Association
Association for the Care of Children's Health
Association for Supervision and Curriculum Development
Association of American Medical Colleges
Association of Maternal and Child Health Programs
Association of State and Territorial Health Officials
Council of Chief State School Officers
The Council of Great City Schools
Healthy Mothers, Healthy Babies Coalition
NAACOG - The Organization for Obstetric, Gynecologic and Neonatal Nurses
National Alliance of Black Educators
National Association of Children's Hospitals and Related Institutions
National Association of Community Health Centers
National Association of Elementary School Principals
National Association for Partners in Education
National Association of Pediatric Nurse Associates and Practitioners
National Association of Public Hospitals
National Association of School Nurses, Inc.
National Association of Secondary School Principals
National Association of State Boards of Education
National Center for Clinical Infant Programs
National Coalition of Hispanic Health and Human Services Organizations (COSSMHO)
National Community Education Association
The National PTA
National Education Association
National Medical Association
National Perinatal Association
National Rural Health Association
National School Boards Association
National School Public Relations Association

National Health/Education Consortium

Good health is a significant determinant of a child's ability to learn and succeed in school. The health and education sectors, however, have historically approached programs and services for children from different perspectives. Recognizing the need for better integration of health and education programs for children, the National Commission to Prevent Infant Mortality and the Institute for Educational Leadership organized the NATIONAL HEALTH/EDUCATION CONSORTIUM.

The project has brought together leaders from over 40 national health and education organizations, representing 11 million constituents, to bridge the separate worlds of health and education into unified action for children. Promoting the full potential of children and providing them with the best opportunities for success will require changes in the systems which currently provide health and education services. Reforms are needed to develop more collaborative and cohesive policies, unify agencies and funding streams, and provide a more comprehensive approach to children's programs.

Toward this end, the NATIONAL HEALTH/EDUCATION CONSORTIUM's activities focus on three major goals: to improve public policy in addressing the need for a better coordinated health and education delivery system; to strengthen communication and dissemination of information between health and education programs and policymakers; and to identify exemplary program models and practices which integrate health and education. Consortium members are working to identify a series of action steps to implement these objectives at the federal, state and local levels. Town meetings involving educators, health professionals, policymakers, administrators, community leaders, advocates and parents will be held throughout the country in an effort to promote community health/education cooperative initiatives.

The NATIONAL HEALTH/EDUCATION CONSORTIUM began in May 1990. The foundation of the Consortium's efforts can be found in the report, *Crossing the Boundaries between Health and Education*, which documents clinical research and programs that exemplify the relationship between children's health and their learning potential. To complement this report, the Consortium is releasing a series of papers which focus on various topics relating to health and education.

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